

## CLAIMS

1. A method of manufacturing a hollow cylindrical body (W2), comprising the steps of:

5 bringing end faces (1, 2) of a plate material (W1), having fingers (7a through 7d) projecting from corners along a joining direction, into abutment against each other to form protrusions (8, 9) projecting along the joining direction with end faces of the fingers (7a through 7d), and  
10 also to form a hollow cylindrical body (W2);

gripping said protrusions (8, 9) and friction-stir-welding abutting regions of the end faces (1, 2) to join the end faces (1, 2) to each other, thereby forming a hollow cylindrical body (W2) having protrusions (8, 9); and

15 removing said protrusions (8, 9).

2. A method of manufacturing a hollow cylindrical body (W2) according to claim 1, wherein said hollow cylindrical body (W2) having protrusions (8, 9) is pressed from the side  
20 of an outer circumferential wall surface thereof when the abutting regions are friction-stir-welded.

3. A method of manufacturing a hollow cylindrical body (W2) according to claim 1, wherein the abutting regions are  
25 friction-stir-welded while said hollow cylindrical body (W2) is inclined with respect to the horizontal direction.

4. A method of manufacturing a hollow cylindrical body (W2) according to claim 1, wherein a wheel rim that is joined to a wheel disk to produce a vehicular wheel is manufactured as said hollow cylindrical body (W2).

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5. A friction stir welding process for bringing a first end face (1) and a second end face (2) of a metal workpiece into abutment against each other, and thereafter joining said first end face (1) and said second end face (2) to each other with a rotating friction stir welding tool (100), wherein when a first end having said first end face (1) is present on a retreating side and a second end having said second end face (2) is present on an advancing side, a workpiece plunging member (104) having a substantially circular cross section, which is disposed on the tip end of said friction stir welding tool (100), is plunged with a central region thereof being displaced from a boundary line (L2) between said first end face (1) and said second end face (2) to said second end within a range equal to or smaller than the radius of the workpiece plunging member (104).

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6. A friction stir welding process according to claim 5, wherein said workpiece plunging member (104) is displaced from said boundary line (L2) to said second end by a distance equal to or smaller than one-half of the radius of the workpiece plunging member (104).

7. A friction stir welding process according to claim 5, wherein a workpiece having said first end face and a workpiece having said second end face are separate from each other and are made of a chief component comprising the same metal.

8. A friction stir welding process for bringing a first end face (1) and a second end face (2) of a metal workpiece having a curved surfaced into abutment against each other to form abutting regions, and then friction-stir-welding the abutting regions to join said end faces (1, 2) to each other, wherein

said first end face (1) and said second end face (2) have burrs (5a, 5b) projecting in the thickness direction of said metal workpiece, and sags (6a, 6b) projecting in a direction transverse to said thickness direction;

when said abutting regions are formed, said sags (6a, 6b) of said first end face (1) and said second end face (2) are disposed in confronting relation to each other and positioned on an outer circumferential wall surface of said curved surface, and said burrs (5a, 5b) are positioned on an inner circumferential wall surface of said curved surface; and

when the abutting regions are friction-stir-welded, a plunging member (104) of a friction stir welding tool (100) is plunged into the outer circumferential wall surface on

which said sags (6a, 6b) are disposed in confronting relation to each other, and thereafter said friction stir welding tool (100) is moved to scan said abutting regions.

5           9. A friction stir welding process according to claim 8, wherein said first end face (1) and said second end face (2) are present on the same metal workpiece, and said abutting regions are provided by curving said metal workpiece to bring said first end face (1) and said second  
10       end face (2) into abutment against each other.

          10. A friction stir welding apparatus (20) for bringing end faces (1, 2) of a plate material (W1), having fingers (7a through 7d) projecting from corners thereof  
15       along a joining direction, into abutment against each other to form a hollow cylindrical body (W2) having protrusions (8, 9), and joining abutting regions to produce a hollow cylindrical body (W2), comprising:

          a base (22);

20           a first columnar member (24) and a second columnar member (26) which are vertically mounted on said base (22);

          a support member (28) for insertion into said hollow cylindrical body (W2) having protrusions (8, 9), and being mounted on and extending between said first columnar member  
25       (24) and said second columnar member (26) when the abutting regions are friction-stir-welded; and

          a first gripping member (30) and a second gripping

member (32) supported on said support member (28) for gripping the protrusions (8, 9), respectively, which are formed when the fingers (7a through 7d) are held in abutment against opposite ends of the abutting regions of said hollow cylindrical body (W2) having protrusions (8, 9), and which extend along a joining direction.

11. A friction stir welding apparatus (20) according to claim 10, wherein said first columnar member (24) has a rotational shaft (42), and said support member (28) has an end coupled to a rotary board (46) fixed to said rotational shaft (42), said friction stir welding apparatus comprising:

a rotating mechanism (52) for rotating said rotary board (46).

12. A friction stir welding apparatus (20) according to claim 10, wherein at least one of said first gripping member (30) and said second gripping member (32) is displaceable toward or away from said protrusions (8, 9) by a gripping member displacing mechanism (64).

13. A friction stir welding apparatus (20) according to claim 10, having outer circumference pressing members (34a, 34b) for pressing said hollow cylindrical body (W2) from the side of an outer circumferential wall surface thereof, said outer circumference pressing members (34a, 34b) having a gap (98) for inserting a rotating friction

stir welding tool (100) for joining the abutting regions of said hollow cylindrical body (W2).

5           14. A friction stir welding apparatus (20) according to claim 13, having an outer circumference pressing member displacing mechanism (86) for displacing said outer circumference pressing members (34a, 34b) toward or away from said hollow cylindrical body (W2).

10           15. A friction stir welding apparatus (20) according to claim 10, wherein said support member (28) is mounted on and extends between said first columnar member (24) and said second columnar member (26) obliquely to a horizontal direction.

15           16. A friction stir welding apparatus (120) for bringing end faces (1, 2) of a plate material (W1), having fingers (7a through 7d) at corners thereof, into abutment against each other to form a hollow cylindrical body (W2),  
20           and friction-stir-welding said end faces (1, 2) to each other, comprising:

          a base (122);

          first support means and second support means which are mounted on said base (122);

25           a support core (32) spaced from said base (122) by said first support means and said second support means, for insertion into said hollow cylindrical body (W2) and for

supporting said hollow cylindrical body (W2); and

a first gripping member (238) and a second gripping member (268) disposed on said support core (32) for gripping respective protrusions (8, 9), which are formed when the fingers (7a through 7d) are held in abutment against opposite ends of abutting regions of said hollow cylindrical body (W2), and which extend along a joining direction;

wherein said support core (32) has passages (258, 260) defined therein for passage of a cooling medium therethrough.

17. A friction stir welding apparatus (120) according to claim 16, wherein said support core (32) comprises a first core member (252) having a curved portion for abutting against an inner circumferential wall surface of said hollow cylindrical body (W2) and a second core member (254) having a groove (256) with said first core member (252) inserted therein.

18. A friction stir welding apparatus (120) according to claim 17, wherein said passages (258, 260) are defined in said second core member (254).

19. A friction stir welding apparatus (120) according to claim 17, wherein said support core (32) is spaced from said first support means and said second support means by being mounted on a support member (130).

20. A friction stir welding apparatus (120) according to claim 17, further including cooling means (320) for cooling a rotating friction stir welding tool (100).

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21. A friction stir welding apparatus (120) for bringing end faces (1, 2) of a plate material (W1) having fingers (7a through 7d) at corners thereof, into abutment against each other to form a hollow cylindrical body (W2), and friction-stir-welding said end faces (1, 2) to each other, comprising:

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a base (122);

first support means and second support means which are mounted on said base (122);

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a support member (130) supported by said first support means and said second support means;

pressing means supported by said support member (130) and movable forward or backward by a displacing means (170), for pressing said hollow cylindrical body (W2) from the side of an inner circumferential wall surface thereof;

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a support core (32) supported by said support member (130), for insertion into said hollow cylindrical body (W2) and for supporting said hollow cylindrical body (W2); and

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a first gripping member (238) and a second gripping member (268) disposed on said support core (32), for gripping respective protrusions (8, 9), which are formed when the fingers (7a through 7d) are held in abutment



against opposite ends of abutting regions of said hollow cylindrical body (W2), and which extend along a joining direction.

5           22. A friction stir welding apparatus (120) according to claim 21, wherein said pressing means comprises:

          a cam (174) movable forward or backward as said displacing means (170) moves forward or backward;

10           a plurality of rods (172) engaging said cam (174) and extending perpendicularly to the direction in which said cam (174) is movable forward or backward; and

          pressers (186) mounted on respective distal ends of said rods (172), for pressing an inner circumferential wall surface of said hollow cylindrical body (W2).

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          23. A friction stir welding apparatus (120) according to claim 21, wherein said support core (32) has a discharge port (274) defined therein for discharging a compressed gas.

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          24. A friction stir welding apparatus (120) for bringing end faces (1, 2) of a plate material (W1), having fingers (7a through 7d) at corners thereof, into abutment against each other to form a hollow cylindrical body (W2), and friction-stir-welding said end faces (1, 2) to each other, comprising:

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          a base (122);

          first support means and second support means which are

mounted on said base (122);

a support core (32) spaced from said base (122) by said first support means and said second support means, for insertion into said hollow cylindrical body (W2) and for supporting said hollow cylindrical body (W2); and

a first gripping member (238) and a second gripping member (268) disposed on said support core (32) for gripping respective protrusions (8, 9), which are formed when the fingers (7a through 7d) are held in abutment against opposite ends of abutting regions of said hollow cylindrical body (W2), and which extend along a joining direction;

wherein either one of said first support means and said second support means is movable toward or away from said support core (32) by a displacing means (148).

25. A friction stir welding apparatus (120) according to claim 24, having a guide member (142) for guiding said first support means or said second support means while said first support means or said second support means is displaced.

26. A friction stir welding apparatus (120) according to claim 24, wherein said first support means or said second support means comprises natural lock cylinders (126, 128), said natural lock cylinders (126, 128) having piston rods (158, 160) that are elevated to support said support core (32) after the natural lock cylinders (126, 128) are

inactivated.

27. A friction stir welding apparatus (120) for bringing end faces (1, 2) of a plate material (W1), having  
5 fingers (7a through 7d) at corners thereof, into abutment against each other to form a hollow cylindrical body (W2), and friction-stir-welding said end faces (1, 2) to each other, comprising:

a base (122);

10 first support means and second support means which are mounted on said base (122);

a support core (32) spaced from said base (122) by said first support means and said second support means, for  
insertion into said hollow cylindrical body (W2) and for  
15 supporting said hollow cylindrical body (W2);

a first gripping member (238) and a second gripping member (268) disposed on said support core (32) for gripping  
respective protrusions (8, 9), which are formed when the fingers (7a through 7d) are held in abutment against  
20 opposite ends of abutting regions of said hollow cylindrical body (W2), and which extend along a joining direction;

two aligning boards (286, 288) held in abutment against an end face of said hollow cylindrical body (W2) and  
disposed one on each side of abutting regions of said hollow  
25 cylindrical body (W2); and

aligning means having a cylinder (188) for pressing said hollow cylindrical body (W2) from the side of an

opposite end face thereof, to displace the hollow cylindrical body (W2) until said one face of the hollow cylindrical body (W2) abuts against said aligning boards (286, 288).

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28. A friction stir welding apparatus (120) according to claim 27, wherein either one of said first gripping member (238) and said second gripping member (268) is displaced by said cylinder (188).

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29. A friction stir welding apparatus (120) according to claim 27, wherein said first gripping member (238) or said second gripping member (268) is displaced and fits over said protrusion (8, 9) of said hollow cylindrical body (W2) after displacement of the hollow cylindrical body (W2) has finished.

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30. A friction stir welding apparatus (120) for bringing end faces (1, 2) of a plate material (W1), having fingers (7a through 7d) at corners thereof, into abutment against each other to form a hollow cylindrical body (W2), and friction-stir-welding said end faces (1, 2) to each other, comprising:

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a base (122);

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first support means and second support means which are mounted on said base (122);

a support member (130) supported by said first support

means and said second support means;

a support core (32) disposed on said support member (130), for insertion into said hollow cylindrical body (W2) and for supporting said hollow cylindrical body (W2);

5 a first gripping member (238) and a second gripping member (268) disposed on said support core (32), for gripping respective protrusions (8, 9), which are formed when the fingers (7a through 7d) are held in abutment against opposite ends of abutting regions of said hollow  
10 cylindrical body (W2), and which extend along a joining direction;

first pressing means (352) supported by said support member (130), for pressing an inner circumferential wall surface of said hollow cylindrical body (W2) vertically  
15 downwardly with a resilient biasing means; and

second pressing means supported by said support member (130) and displaceable by displacing means (170) for pressing an inner circumferential wall surface of said  
20 hollow cylindrical body (W2) horizontally.

31. A friction stir welding apparatus (120) according to claim 30, having presser stop means (290a, 290b) for pressing said hollow cylindrical body (W2) from the side of an outer circumferential wall surface thereof to a stop.